Journal of Textile Engineering & Fashion Technology

Mini Review

Fashion requirements influencing sensorial and thermal comfort of clothing

Volume 8 Issue 6 - 2022

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Received: October 07, 2022 | **Published:** November 08, 2022

Abstract

Fashion experts when designing new clothing firstly focus their attention on design, style, colours and fit of the product, and then they have to consider structure and materials of the developed garment. However, all these components of the garment design, namely the fabric structure, composition and finishing will influence the sensorial and thermal comfort of clothing. In the paper, selected parameters of clothing comfort, namely fabric drape, friction coefficient and thermal & evaporation resistance as well as special methods of their testing are shortly described, and the possible effect of these paramaters on clothing design is outlined.

Introduction

Fashion is commonly referred to the prevailing style of dress or behaviour that it is characterized by change.[1] This constant change determines the different fashion's requirement such as design, style, colours and selection of the used fabrics which may significantly influence sensorial and thermal comfort of clothing, both in the positive, but also in the negative sense.[2–4] Unfortunately, the university and college courses of fashion design rarely deliver enough information and knowledge to young designers, regarding the fabric parameters, which may influence sensorial and thermal comfort of clothing. Some of these missing information and knowledge are outlined in the paper.

There are three categorized areas in clothing comfort; physiological/ ergonomic which concerned with the thermal regulation of the body; the sensorial/tactile/ physical comfort relates to moisture sensations such as dampness, wetness, clinginess and pressure sensations dealing with garment being tight or loose fit, soft or heavy; and last the psychology aspect of clothing.[5]

The physiological and physical side of garment that bring comfort are not fully explored by fashion designers as their aims are mainly focus on visual and aesthetic appeal.

This paper covers the sensorial/tactile and thermophysical comfort of fabrics looking at their different parameters and testing instruments to measure their performance.

Sensorial properties

Easiness of mobility of a clothed wearer depends firstly on the mass of clothing and on bending and shearing stiffness levels of particular parts of clothing, namely on the complex stiffness of arm zones, elbows, knee zones and waist zones. Here, the bending stiffness is strong function of the used simple or multilayer fabrics – it increases roughly with 3rd power of the total fabric thickness, provided that all layers are mutually connected by sewing or thermal fusing. This aspect is very important when designing multilayer protective clothing e. g. for firefighters.

Contrary to non-linear very strong effect of thickness on bending stiffness of fabrics, shearing stiffness is just linearly dependent on the thickness.[6] However, some textile structures, such as nonwovens or laminated fabrics, are principally very stiff, as they do not allow free motions of yarns in the fabric volume. Thus, protective clothing like military or firefighter´s uniforms involving laminated membranes do not allow the use of slim, good - looking sleeves or trousers, as mobility in narrow tubes would evoke high mechanical resistance.

Sometimes, also the colour of clothing can influence significantly its thermal comfort.[7]

Regarding the shearing stiffness, the fashion experts sometimes underestimate this parameter of fabrics creating clothing, as fabrics with good level of sensorial comfort may not satisfy the fashion requirements, by making the clothing silhouette too bulky and heavy – handed. Contrary to relative easy testing of bending stiffness of fabrics, determination of shearing stiffness requires a complicated tester. That is why clothing designers sometimes test the complex deformability if fabrics by their drape. New simple method of fabric drape testing was developed in the Technical university of Liberec. As follows from the next Figure 1, the method depends in determination of a co-sinus of the angle DA between the inclined linear edge of draped squared fabric and the planar surface of a table, where the tested fabric is fixed. The DA coefficient can be tested for both weft a warp directions.

Figure 1 Determination of the DA coefficient.

The correlation coef. R^2 between DA and DC for common weaves is about 70%, see the comparison on Figure 2. DA coefficient then depends on the fabric square mass W, bending stiffness B and shearing stiffness G by the equation

$$DA = C_0 - C_1\,(B/W)^{0,33} - C_2\,(G/W)^{0,33}$$

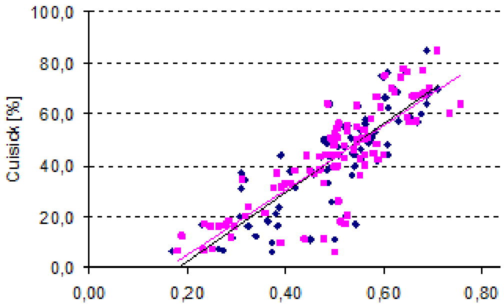

Figure 2 DA versus standard Drape Coef. by Cuisick.

Here, C_0,C_1 and C_2 are experimental constants, specific for each tested fabric.[8] As already mentioned, laminated fabrics, coated fabrics, nonwovens and non – elastic foils exhibit very high shearing stiffness, only woven and knitted fabric allow easy relative motion of yarns and fibres in the fabric structures, thus offering mostly low shearing stiffness.

Important component of sensorial comfort of clothing present friction properties of the used fabrics against themselves, or against skin. Some garments, like linen and internal fabric of sleeves, require low friction against underwear od shirts, but most of the clothing fabrics exhibit medium level of friction, which provide pleasant contact feeling. There are many instruments for determination of fabric friction on the market. The best of them, like the KES testers from Japan, employ the principle, where the sensing unit is fixed and the tested fabric is moving. This solution excludes the effect of acceleration of the moving sensor on the measured total force. One of these testers is the FRICTORQ computer operated instrument developed in Portugal – see in the Figure 3. The torque momentum in the sensing disc is measured by a steady sensor, whereas the measured fabric rotates.

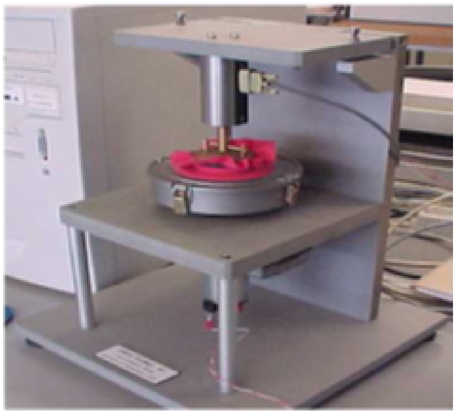

Figure 3 FRICTORQ fabric friction tester based on rotation of the tested sample.

Due to its robust design, this instrument measures reliably (with low level of CV) friction of dry fabrics as well that of fabrics in the wet state. In the area of sensorial comfort, excess of moisture in fabrics would originate the wet contact feeling, called clinging. That is why some parts of clothing should be made of fabrics which absorb moisture and do no create a thin viscous film between a skin and a first contact fabric. However, some hydrophilic fabrics auch as cotton ones at higher moisture level may provide high friction level which causes the mentioned clinging effect – see in the Figure 4. Here, application of a suitable finishing would be very helpful.[9]

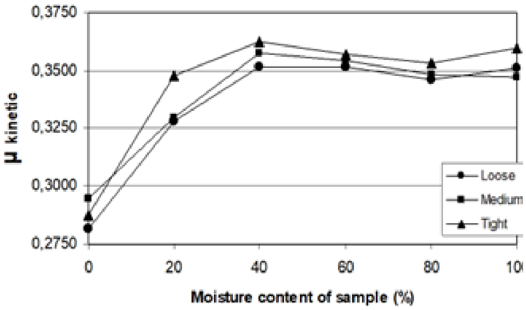

Figure 4 The effect of moisture on friction coefficient of cotton knits.

Thermal insulation and thermal contact properties

The most important parameters characterizing thermo-physiological comfort of leisure, sport and protective garments are water vapour permeability and thermal insulation, the latter measured in the units of thermal resistance R [m^2K/W].[10] This parameter increases with the fabric thickness h, and depends on its thermal conductivity λ [W/m/K] according the equation

$$R = h/\lambda$$

Where the level of thermal resistance of clothing must be optimized (according to the climatic conditions), water vapour permeability (WVP) of the used fabrics must be as high as possible. Only very WV permeable highly porous fabrics enable the inevitable cooling of the body by the sweat evaporation. WVP generally decreases with increased fabric thickness and depends on its structure, material composition and finishing, but also on the clothing design. However, manufacturers of fashionable protective jackets do not respect the fact, that excessive use of pockets, shields, badges, emblems and printed zones on the clothing surface may drastically reduce the effective WVP. Any pocket attached on the clothing surface presents doubling the water vapour trajectory and doubles the local water vapour resistance.[11]

Thermal absorbtivity b of fabrics, an important parameter of sensorial comfort of fabrics was introduced by Hes[12] to characterise thermal feeling (heat flow level) during short contact of human skin with the fabric surface. For time of thermal contact τ between the human skin and the object, shorter then several seconds, the measured fabric can be simplified into semi-infinite homogenous mass with thermal capacity ρc [J/m^3] and initial temperature t_2. Unsteady temperature field between the human skin (with temperature t_1) and fabric with respect to of boundary conditions offers a relationship, which enables to determine the heat flow q [W/m^2] course passing through the fabric:

$$q = b\,(t_1 - t_2) / (\pi\tau)^{1/2},\ b = (\lambda\rho c)^{1/2}\,[Ws^{1/2}/m^2/K]$$

where ρc [J/m^3] is thermal capacity of the fabric and the term b presents thermal absorbtivity of fabrics. The higher is thermal absorbtivity of the fabric, the cooler is its feeling. In the textile praxis this parameter ranges from 20 $Ws^{1/2}/m^2K$ for fine nonwoven webs to 600 $Ws^{1/2}/m^2K$ for heavy wet fabrics. The fabric moisture can significantly increase thermal absorptivity of fabrics (presenting cooler contact feeling), due to relatively high thermal conductivity of water: 0,61W/m/K. Thermal absorptivity and thermal resistance of fabrics or the whole clothing can be determined by the non- destructive tester ALAMBETA presented in the Figure 5, which also measures the fabric thickness, with repeatability of 10 micrometre.

Figure 5 The ALAMBETA thermal tester.

Thermal resistance of fabrics decreases with the increasing fabric moisture that is why the thermal insulating fabrics and fibre webs must be based on hydrophobic polymers. There were attempts to produce quality thermally insulating blankets, cushions, protective construction webs etc out of short cotton fibres, jute and other hydrophilic plant fibres, without real effect, unless these fibres were hydrophobized.

Special moisture related properties exhibit wool fibres. Thanks to the hydrophobic nature of non-treated wool fibre surface, these fabrics keep their good thermal insulating properties as well as dry warm) contact feeling up to 30–40% of their relative moisture. Water keeps absorbed in the central part of the fibre. However, exaggerated antifelting treatment may deteriorate these extraordinary wool thermal comfort properties.[13] The ALAMBETA tester, due to short time of measurements, enables a reliable determination of thermal properties of fabrics in wet state also.[14]

A recent development in the area of thermo-physiological comfort includes an attempt to develop a software that can be used as a tool by textile technologists to determine the optimum fabric construction parameters for different permutations of thermo-physiological comfort parameters and thermal contact feelings; for instance, high thermal insulation coupled with cool contact feeling or high water-vapour permeability with warm thermal contact effect.[15]

Water vapour permeability of fabrics

Coming back to the above mentioned very important parameter of thermo-physiological comfort of clothing, water vapour resistance Ret [m^{2}Pa/W] or gravimetrically determined water vapour permeability MWTR [g/m^2/24 hours], it should be emphasized, that this parameter cannot be replaced by knowledge of air permeability of fabric, due to the different transfer mechanisms.

There is a big problem of fashion experts, when designing multilayer protective clothing like military or firefighter´s uniforms and outdoor jackets requiring the highest water vapour permeability (WVP): their design and fabric selection is based on WVP (Ret) data of individual fabrics creating the final clothing. Moreover, the designers mostly rely on data from fabric material sheets, but these data might have been determined according to uncertain methods or standards. Different standards on testing of WVP of fabrics on gravimetric principle may measure the moisture transfer at different temperature of the measuring system containing water, which would influence the level of saturated WV pressure, serving as the driving force. Thus, MWTR data determined by different standards may provide results differing up to + 100%. When the designed clothing consists of fabrics with their own Ret or MWTR levels, then the resulting level Ret or MWTR can be much lower than the data presented in the data sheet of the basic textile fabric (often used as the reference value in the marketing of a product).

Now, how the clothing designer can discover the true about the WVP of the final product? MWTR data of individual fabrics determined gravimetrically is not possible to sum up – they do not express the evaporation resistance of a fabric, just mass flow, which is influenced by the evaporation resistance of the air boundary layer above the tested sample. To get the MWTR of the whole fabrics system, the testing operator should compose this system and cut it into a special shape, with sealed edges. This unstable multi-layered fabric will be then tested gravimetrically.

Contrary to that, values of water vapour resistance Ret of individual fabrics, determined by the Skin model type instruments, can be summarized.[6] Skin models also enable easier testing of Ret of multi-layered fabric system, without the necessity of sealing the fabric edges – special protective guarding ring reduces the water vapour outflow. The main disadvantage of common Skin models is the necessity to cut a large fabric sample into a special shape, which is then inserted into the limited space of the tester. Despite of it, common Skin models present reliable and frequently used tool for determination of evaporation and thermal resistance of multilayer fabrics of and thick fibre webs.[16] In last decades, another type of Skin model appeared in the market. This relatively small and portable PERMETEST tester of evaporation and thermal resistance of textile and other planar fabrics presented in the Figure 6 measures on same principle as the common Skin models, but due to new principle of double calibration, it can be operated very quickly and in any space with moderate temperature and. Energy consumption moisture of this device (without the connected external PC) is just 40W.

Figure 6 PERMETEST non - destructive thermal comfort tester.[11]

Standard fabric can be measured within 5 minutes. Results are treated statistically and the Ret and Rat results are expressed in the ISO 11092 units.[16] From several circular tests executed among various laboratories follows that the PERMETEST results are in very good agreement with the results determined on common Skin models.

The largest advantage of this tester is the possibility to test the complex multi-layered fabric systems, in means the real clothing, without the necessity of cutting the clothing into special shape. Thus, the negative effect of pockets, strips, emblems, components of portable electronics etc. on the final level of evaporation and thermal resistance of the protective clothing can be easily and quickly determined. This tester, due to short time of measurements, enables a reliable determination of water vapour permeability of fabrics in wet state also.

Conclusion

In the paper, selected comfort parameters, which may influence the design of clothing, namely fabric drape, friction coefficient and thermal & evaporation resistance are shortly described and innovative methods of their testing are presented. These methods exhibit ease of operation, short time of measurement and the presented evaporation and thermal resistance testers are non-destructive. From the study follows the importance of knowledge of sensorial and thermal properties of textile fabrics for textile & fashion designers, as these comfort parameters may strongly influence the practical applicability the newly designed textile products.

Acknowledgments

None.

Funding

None.

Conflicts of interest

The authors declare no conflict of interest.

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Citation: Hes L, Unmar R, Iranah SR. Fashion requirements influencing sensorial and thermal comfort of clothing. *J Textile Eng Fashion Technol.* 2022;8(6):173–176. DOI: 10.15406/jteft.2022.08.00318